

# THE DEVELOPMENT OF FISH POPULATION-BASED BIOCRITERIA IN VERMONT

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## Abstract

The Vermont Department of Environmental Conservation is presently modifying two fish population-level indices for potential use as biocriteria in permit compliance and stream classification. Modifications of Karr's Index of Biotic Integrity and Pinkham and Pearson's similarity coefficient (PPSC) were selected for use in defining the water quality standard, "undue adverse effect on the aquatic biota". A modification of Karr's IBI for the Northeast by Miller et al. provided a starting point in adopting the IBI for Vermont's species depauperate wadeable streams. Omernick's ecoregion format was used to establish ecoregional species richness standards used by the Vermont version. The PPSC was modified to more heavily weigh contrasts between the more dominant species. The calibration of both indices is in progress. The IBI has been applied to data from 44 sites on 28 streams while the PPSC has been applied at eight sites. The Vermont IBI has not responded fully to every type of community disturbance, i.e. flow regulation and some toxins. Aside, however, from being a highly integrative index, scoring of the IBI does provide a framework of metric assessment permitting analysis of individual community attributes; an advantage in applying professional biological judgement. The PPSC appears to be sensitive to any shift in compositional and abundance changes, but computation of the index value reveals little descriptive information on either contrasted community. The potential weakness of each index seems to be compensated for by the other when used concurrently in control-test comparisons.

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## Introduction

Specific biocriteria have been proposed by the Vermont Department of Environmental Conservation which use macroinvertebrate communities in determining in-stream compliance of indirect dischargers through the Indirect Discharge Program. A macroinvertebrate sampling and analysis protocol is in place which defines "significant impact to the aquatic biota" in making this determination. Since activities leading to the development of appropriate fish population descriptors have taken place at a slower rate, formally proposed fish-based biocriteria have yet to be presented. The overall objective of this effort is to generate a systematic method of evaluating the

integrity of the fish community which can be utilized in an analogous manner to the macroinvertebrates protocol but which defines the less vigorous Water Quality narrative criterion, "undue adverse effect to the aquatic biota". The Department also recognizes the potential for fish population assessment in monitoring and stream classification programs. This manuscript describes the process by which two biological indices were selected and are being modified for use on fish communities in wadeable streams in Vermont. This effort can be partitioned into two steps: 1) selection and verification of indices, and 2) integration of these indices into compliance and monitoring programs as biocriteria.

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Table 1. Considerations in Developing Fish Population Biocriteria in Vermont.

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Specific Index Requirements

1. Must measure integrity of entire fish population;
2. Must accurately measure fish population responses to physical habitat degradation as well as point and nonpoint water quality impacts;
3. Must have low variability of known quantity;
4. Must be applicable to a variety of stream habitats.

Data Quality Requirements

1. Must develop standardized physical habitat assessment method for site comparison;
2. Must establish sampling protocols
  - a. Sampling method
  - b. Sampling effort
  - c. Site selection

Biocriteria Considerations

1. Relate index results to narrative criteria (integrate use of index into Water Quality Standards).
  2. Must systematically establish professional judgement as an input to decision making process.
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Modifications of Karr's (1981) Index of Biotic Integrity (IBI) and the similarity coefficient of Pinkham and Pearson (PPCS) (1976) were selected for use. The verification and calibration effort for both indices is still in progress. To date, the IBI has been applied to 76 sites on 43 streams. No in-depth evaluation of our results will be presented here due to the incomplete data base. The discussion will include the rationale used to modify both indices, some general interim results and finally, information needs to be addressed.

**Methods and Materials**

The development of fish population-based biocriteria began in 1986. In the first two years data used in the index testing often originated from other sampling programs. For 1988, however, significantly more time has been allotted specifically for IBI-PPCS

verification. While general goals were defined at the onset of these activities, specific objectives and concerns for data requirements evolved as the work progressed. Future efforts will address specific information needs that were generated from past work. The principle data requirements and general concerns appear in Table 1.

**Vermont Stream Populations**

In characterizing fish community attributes of wadeable streams, historical data was organized by ecoregion (Omernick 1987). Vermont, a small state, contains only three ecoregions, one of which, the Northeastern Coastal Zone appears to include too small an area to be treated separately (Figure 1). Most of the state is covered by the Northeastern Highlands (NEH). This ecoregion, characterized by relatively high elevations, includes the Green Mountains, the Vermont Piedmont and the (Vermont)

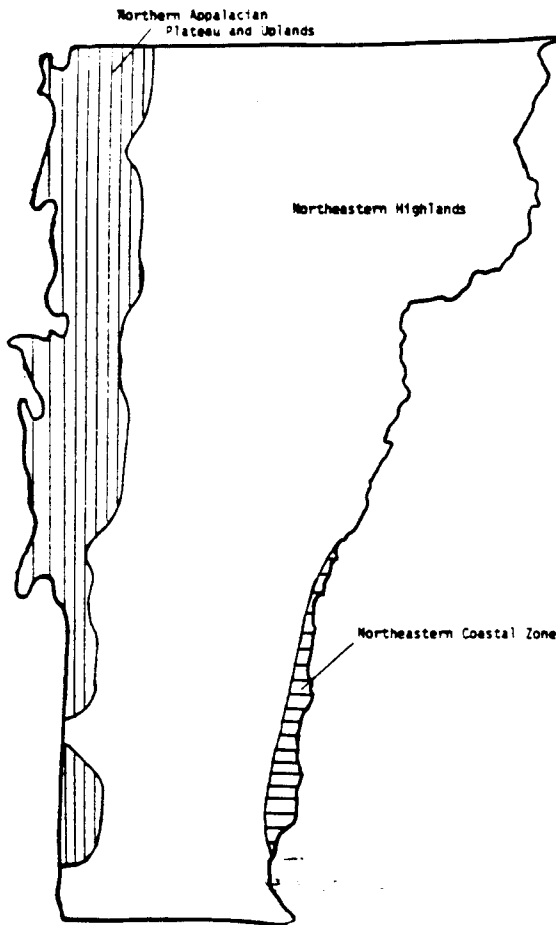


Fig. 1. Ecoregions of Vermont from Omernik 1987.

Northeastern highlands. The other major ecoregion, the Northern Appalachian Plateau and Uplands (NAPU) span the Eastern third of the state, including the Champlain Valley and lower elevations of the Taconic Mountains.

Available data indicate that Vermont stream communities are relatively species-depauperate with most streams supporting fewer than ten species. Figures 2 and 3 plot species richness by sampling site drainage area for both major

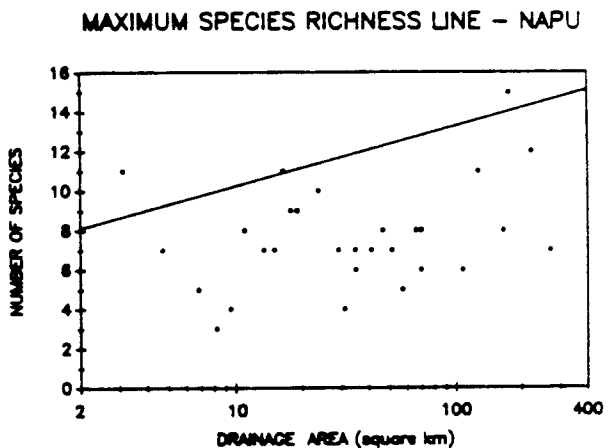
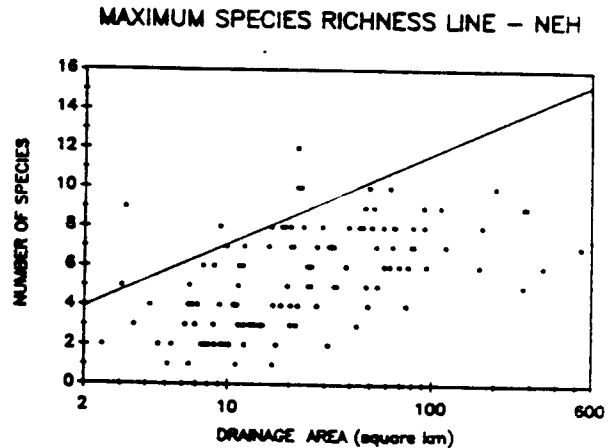


Fig. 2. Maximum species richness lines for NEH.

Fig. 3. Maximum species richness lines for NAPU.

ecoregions. Streams in the NEH are generally dominated by insectivores. Headwater reaches often contain only brook trout. Species additions, progressing downstream, commonly include slimy sculpin, blacknose and longnose dace followed by creek chub, white suckers, fallfish, brown and rainbow trout. A small number of additional cyprinids, tessellated darter and one to three centrarchids may complete the community in the lower reaches of

Table 2. A preliminary IBI for Vermont.

<u>Scoring Criteria</u>			
	5	3	1
<u>Species Richness and Composition</u>			
1. Total number of fish species	Medium species richness lines		
2. Number and Identity of Tolerant Species	>1	1	0
3. Number and Identity of Benthic Insectivores	>2	1-2	0
4. Proportion of Individuals as White Sucker	<10%	10-25%	>25%
<u>Trophic Composition</u>			
5. Proportion of Individuals as Generalist Feeders	<20%	20-45%	>45%
6. Proportion of Individuals as Insectivores	>65%	30-65%	<30%
7. Proportion of Individuals as Top Carnivores:			
Cold water	>10%	3-10%	<3%
Warm water	>5%	1-5%	<1%
<u>Fish Abundance and Condition</u>			
8. Abundance in Sample	moderate to high	low	very low
9. Proportion of individuals with disease, tumors, fin damage and other anomalies	0-1%	1-3%	>3%

larger streams. Species richness in NAPU streams appears to be slightly greater than in NEH streams of similar drainage area. The total species list from NAPU streams includes most species from the NEH plus an additional fifteen species (mostly cyprinids and darters) not found in the NEH streams. Data collected to date suggests that longitudinal species addition seems to occur at a higher rate in NAPU streams. Most streams of this ecoregion support warmwater populations, devoid of trout.

#### The Vermont IBI

It was recognized early that if the IBI concept was to be applied to Vermont's streams that extensive modification of the midwest original (Karr 1981) would be required. Following a review of two IBI modifications from Karr's original for Eastern streams, the

modification by Miller et al. (unpublished manuscript) for Merrimack (New Hampshire) and Connecticut (Massachusetts) drainages was selected as a starting point. The present nine-metric Vermont IBI (Table 2) contains eight of twelve metrics from Miller et al. Some of these metrics were rescored or modified. One metric was taken from the modification of Leonard and Orth (1986).

An IBI is applied by assigning a score of 5, 3 or 1 to each metric. A score of "5" denotes full agreement with conditions from a relatively unimpacted site while a "1" represents the greatest deviation from that expected. A score of "3" reflects an intermediate level of deviation. Metric scores are summed, with the resultant value placed into a qualitative category ranging from very poor (low score) to excellent

Table 3. Fish Species occurring in Vermont Streams considered as intolerant to general habitat and Water Quality degradation based on published literature accounts.

Brook trout	Chain pickerel
Brown trout	Cutlips minnow
Slimy sculpin	Northern Redbelly dace
Blackchin shiner	Silvery minnow
Blacknose shiner	

(high score). A brief discussion of the rationale for each metric from the Vermont IBI follows.

Metric 1. Total Number of Species.

Lines of maximum species richness were generated from historical data from 154 streams sampled by the Vermont Departments of Fish and Wildlife and Environmental Conservation (Figures 1 and 2). These lines represent ecoregional standards. Following Karr's (1981) methods, a fit-to-eye line was drawn to include 95% of the data and to follow the general slope of the plot. Two other lines, approximately trisecting 95% of the data below the maximum species richness were scored according to Karr. A general, though not well developed, trend of increasing number of species with stream drainage area was observed for both ecoregions. This metric appears only to be sensitive at moderate to severe levels of degradation as reflected by the present Vermont IBI data base.

Metric 2. Number and Identity of Intolerant Species. This metric is often scored by the use of a line of maximum species richness (Karr 1981; Miller et al. unpublished). Since species richness in Vermont streams is low, any variation in the numbers of intolerant species expected between sites and ecoregions has not

been detected as yet. As a result, one set of scores has been assigned to all streams. Eleven species have been classified as intolerant based on the available literature (Table 3).

Metric 3. Number and Identity of Benthic Insectivores. Since stream habitat degradation may represent the greatest threat to aquatic biota in Vermont, the inclusion of metrics sensitive to a wide breadth of feeding preferences is of particular importance. An unstable benthic macroinvertebrate community in the presence of degraded conditions threatens those fish species which rely on that community as a primary food base (Karr 1986). Insectivores dominate fish communities in healthy streams in both Vermont ecoregions. As with metric 2, no variation between sites or ecoregions has been observed and one set of scores has been assigned to all streams. A typical undisturbed stream supports from one to three benthic insectivores. Trophic classification follows the available literature (Table 4).

Metric 4. Proportion of Individuals as White Sucker. This species was selected due to its ubiquitous distribution in both ecoregions. The white sucker is commonly

regarded as tolerant to many forms of degradation (Trautman 1981; Twomey 1984). As generalists feeders (Miller et al. unpublished; Leonard and Orth 1986) they are better suited to a shifting food base in the presence of degraded conditions than are more specialized feeders (Karr et al. 1986). Thus far white sucker have only occurred in higher densities in degraded sites. This metric follows the substitution by Miller et al. of white sucker for Karr's green sunfish metric as a tolerant species.

Metric 5. Proportion of Individuals as Generalist Feeders. Leonard and Orth (1986) substituted this metric for Karr's omnivore metric because 1). the omnivore classification was believed too restrictive in defining species which were able to shift food habits in response to a variable food base, and 2). some generalist feeders, i.e. creek chub were not classified as omnivores yet, were very tolerant to many forms of perturbation. Use of the omnivore classification resulted in a conflict in scoring metrics (and a less responsive index). The placement of creek chub and fallfish into the generalized feeder category with true omnivores appears to be appropriate in that Semotilus in Vermont streams is generally observed as a dominant only in degraded stream reaches. This metric will usually vary inversely in scoring with metrics 3, 6 and 7.

Metric 6. Proportion of Individuals as Insectivores. Miller et al. substituted this metric for Karr's insectivorous cyprinids metric due to the paucity of insectivorous cyprinid species in streams of the Northeast. This was also deemed a reasonable substitution for Vermont

streams. This metric is comparable in function to metric 3 (benthic insectivores species) but includes surface and midwater feeders as well.

Metric 7. Proportion of Individuals as Top Carnivores. This metric is analogous to the top level carnivore metric of Miller et al. and others. Since a significant portion of streams in Vermont support naturally reproducing trout, the three trout species (as well as burbot) are included as top carnivores. Since unimpacted wadeable streams appear to contain trout and warmwater piscivores at different densities, two scoring ranges have been established. For sites represented by both groups, the group scoring the highest will be represented in the metric. The modification of Miller et al. excluded from consideration upland coldwater sites which support trout. The author does not believe that the presence of trout and a low number of other species at a site precludes application of an IBI. It is believed that enough information exists to accurately score the IBI if a generalist feeder and at least three other non-salmonid species are present. This condition represents a proposed minimum criterion for applying the Vermont IBI.

Metric 8. Abundance of Sample. More data is presently needed to calibrate this metric. Since a wide range of productivity exist in Vermont streams and since yearly variation in this parameter is high, this metric will probably be scored conservatively. Thus far, as Karr et al. (1986) recommends, catch per unit effort (CPUE) has been used in scoring this metric.

Table 4. Trophic Classification of Vermont's Stream Fishes.  
Determinations are based on the published literature.

TOP CARNIVORE

Chain Pickerel (Esox niger)  
Northern Pike (Esox lucius)  
Largemouth Bass (Micropterus salmoides)  
Smallmouth Bass (Micropterus dolomieu)  
Rock Bass (Ambloplites rupestris)  
Brook Trout (Salvelinus fontinalis)  
Brown Trout (Salmo trutta)  
Rainbow Trout (Salmo gairdneri)  
Burbot (Lota lota)

BENTHIC INSECTIVORES

Blacknose Dace (Rhinichthys atratulus)  
Longnose Dace (Rhinichthys cataractae)  
Cutlips Minnow (Exoglossum maxilllingua)  
Slimy Sculpin (Cottus cognatus)  
Mottled Sculpin (Cottus bairdi)  
Shorthead Redhorse (Moxostoma macrolepidotum)  
Eastern Sand Darter (Ammocrypta pellucida)  
Tessellated Darter (Etheostoma olmstedii)  
Logperch (Percina caprodes)

INSECTIVORE

Blackchin Shiner (Notropis heterodon)  
Emerald Shiner (Notropis atherinoides)  
Rosyface Shiner (Notropis rubellus)  
Spotfin Shiner (Notropis spilopterus)  
Spottail Shiner (Notropis hudsonius)  
Blacknose Dace (Rhinichthys atratulus)  
Longnose Dace (Rhinichthys cataractae)  
Cutlips Minnow (Exoglossum maxilllingua)  
Finescale Dace (Phoxinus neogaeus)  
Bluegill (Lepomis macrochirus)  
Pumpkinseed (Lepomis gibbosus)  
Redbreast Sunfish (Lepomis auritus)  
Slimy Sculpin (Cottus cognatus)  
Mottled Sculpin (Cottus bairdi)  
Eastern Sand Darter (Ammocrypta pellucida)  
Iowa Darter (Etheostoma exile)  
Tessellated Darter (Etheostoma olmstedii)  
Logperch (Percina caprodes)  
Yellow Perch (Perca flavescens)  
Shorthead Redhorse (Moxostoma macrolepidotum)  
Banded Killifish (Fundulus diaphanus)  
Brook Stickleback (Culaea inconstans)  
Trout-perch (Percopsis omiscomaycus)

GENERALIZED FEEDER

Blacknose Shiner (Notropis heterolepis)  
Bluntnose Minnow (Pimephales notatus)  
Common Carp (Cyprinus carpio)  
Common Shiner (Notropis cornutus)  
Creek Chub (Semotilus atromaculatus)  
Fallfish (Semotilus corporalis)  
Fathead Minnow (Pimephales promelas)  
Golden Shiner (Notemigonus crysoleucas)  
Lake Club (Couesius plumbeus)  
Mimic Shiner (Notropis volucellus)  
Northern Redbelly Dace (Phoxinus eos)  
Pearl Dace (Semotilus margarita)  
Sand Shiner (Notropis stramineus)  
Eastern Silver Minnow (Hybognathus regius)  
Black Bullhead (Ictalurus melas)  
Brown Bullhead (Ictalurus nebulosus)  
Stonecat (Noturus flavus)  
Longnose Sucker (Catostomus catostomus)  
White Sucker (Catostomus commersoni)  
Fantail Darter (Etheostoma flabellare)  
Mudminnow (Umbra limi)

Metric 9. Proportion of Individuals with Disease, Tumors, Damage and Other Anomalies. This metric has a relatively narrow range of application in Vermont as it is sensitive to only severe degradation (Karr et al. 1986). The most common anomaly thus far is heavily infestations of black spot (Neascus sp.). Steedman (1988) substituted the occurrence of black spot alone for Karr's original metric, as this was the predominant anomaly in streams in the Toronto area.

Three metrics from the modification of Miller et al. were not used in the Vermont IBI.

Metric 2. Number and Identification of Native Water Column Species.

This is a substitute metric for Karr's original number of sunfish species metric. It was not included in the Vermont IBI because of the probable conflict in scoring with the generalist feeder metric. many water column species, i.e. creek chub, fallfish, common shiner and golden shiner) are omnivores and generalist insectivores. The two metrics then would most likely cancel each other by scoring, in opposite directions, a species which is both opportunistic and a water column feeder. Low species richness in Vermont streams may also be responsible for the preclusion of the water column feeder metric.

Metric 4. Number and Identity of Sucker Species. Only two sucker species are known to inhabit wadeable streams in Vermont. While the white sucker is generally regarded as tolerant to many forms of degradation, the longnose sucker is believed to have a narrower range of habitat tolerances

Table 5. An example of the FPCS (Pinkham and Pearson 1976) (A) and the weighted modification of that version (B).

A. Abundance

	Site A	Site B	Quotients
Species A	100	75	$75/100 = 0.75$
B	10	50	$10/50 = 0.20$
C	1	10	$1/10 = 0.10$
D	1	0	$1/0 = 0$
			$1.05/4 = 0.26 = B$

B. Abundance

	Site A	Site B	Quotients	Factor	Quotients
Species A	100	75	$75/100 = 0.75$	$2.00 =$	$1.50$
B	10	50	$10/50 = 0.20$	$1.25 =$	$0.25$
C	1	10	$1/10 = 0.10$	$1.00 =$	$0.10$
D	1	0	(not included)	$4.25$	$1.85$
			$4.25/1.85 = 0.44 = B$		

(Edwards 1983). Karr's intent was to equate greater numbers of sucker species (most of which were intolerant) with higher site integrity. Clearly then, this metric would be inappropriate for use in Vermont streams.

**Metric 11. Proportion of Individuals as Hybrids.** To date, few hybrids have been identified in Vermont streams. A problem exists in the accurate field identification of hybrid cyprinids, the group in Vermont most likely to exhibit this phenomenon.

A condition of the modification of Miller et al. excluded exotic species from the scoring of all but one metric. Exotics were viewed as part of the degradation. Because of a general lack of severely impacted sites combined with the existence of physical barriers prohibiting extensive upstream movement, exotic non-salmonid species do not comprise a significant component of wadeable streams in Vermont. Exotic trout species (brown and rainbow) are included in the scoring of the Vermont IBI under the following conditions: 1) the site or reach sampled can support natural

reproduction of those species, and 2) sampling to take place at a location and time, that is enough removed from (1 km, 3-4 months) from the stocking site and time.

Some Proposed Guidelines for the Application of the Vermont IBI

A minimum criterion of four non-salmonid species, including a generalist feeder, must be met to apply this index. In control-test site comparisons this prerequisite applies to the control populations only. All sampling must be conducted between mid-August and mid-October. This period corresponds to the yearly low flow period permitting most efficient sampling. Since small fish are not as vulnerable to electrofishing gear (Nielson and Johnson 1985) only fish larger than 25 mm total length will be included in the index. Stocked Atlantic salmon fingerlings will be excluded from index consideration due to their inability (as yet) to spawn in streams. Abundance of fingerlings on certain reaches can be high due to high stocking densities and absence of sportfishing mortality.

Fishing effort required remains a less-easily defined guideline. Minimum effort in the sampled reach has not yet been determined. The choice exists as one between a one to two sweep CPUE and the multiple-sweep population estimator of Carle and Strub (1978).

Physical habitat conditions have been shown to be an important determinant of fish distribution (Gorman and Karr 1979; Horowitz 1978; Schlosser 1982). Hendrick et al. (1980) identified the process of selecting control and test sites that are similar in habitat as "one of the most difficult problems encountered in the biomonitoring of fish". While trained professionals can often select two sites, like in habitat (Hendricks et al. 1980), it is believed that a form of documentation of that likeness is necessary. A systematic method of habitat analysis then, will likely be required for all biocriteria related population sampling. This analysis will provide a measure of habitat similarity between control and test sites. This measure is of importance in cases where: 1) water quality impairment is suspected and differences in physical habitat are to be minimized, and 2) changes in habitat are to be documented at sites where a physical habitat-related impairment is suspected.

Although the quantity of area sampled varies in published studies, most investigators strive to sample all major habitat types in attempting to produce a fully representative sample (i.e. Mahon 1980; Berkman et al. 1986; Larson et al. 1980; Leonard and Orth 1986; Steedman 1988). Karr et al. (1986) suggests a minimum length of 100 m for structurally simple streams. For larger, more complex (habitat diverse) streams, Karr et al. (1986) suggests a minimum of two habitat

cycles. Leonard and Orth (1986) included two habitat cycles in their 50 m length sites in small West Virginia streams. Hankin (1986) stressed the importance of sampling with regard to habitat type rather than pre-established site length. He maintained that sampling habitat-defined sections minimized errors in estimating abundance when compared to length-defined site estimates. It is likely that a combination of minimum distance and number of habitat cycles will be incorporated into Vermont's sampling requirements.

#### Index of Biotic Similarity

A modification of Pinkham and Pearson's (1976) PPCS (B) is proposed for concurrent use with the Vermont IBI. Use of the Vermont IBI to date, indicates that it may not be completely responsive to all perturbations, i.e. flow regulation and some toxins. The PPCS appears to be sensitive to any change in species abundance or composition within a community. A disadvantage of the PPCS is that the index value as well as the computation of that value provide little information on the nature of the community itself. Simultaneous use of both indices would appear to combine the positive aspects of sensitivity (PPCS) and description of community parameters (IBI) into the final biocriterion.

The PPCS produces a measure of similarity (0-total dissimilarity to 1.0-total similarity). For use in water quality standards compliance, the implicit assumption is made that an altered or stressed population will, when contrasted to a control population, exhibit progressively lower values (towards

dissimilarity) with increasing population impact.

The PPCS is:

$$\frac{1}{k} \sum_{i=1}^k \min \frac{X_{ia}, X_{ib}}{\max X_{ia}, X_{ib}}$$

where k = number of comparisons between sites;

x = number of individuals in taxon i;

a,b = Site A, Site B

An example illustrates the computation of the formula in Fig. 5-A.

In its present form, the index weighs contrasts between all species equally, regardless of their dominance in the community. Pinkham and Pearson (1976) stated that in cases where organisms from the same trophic level are to be contrasted, it may be more desirable to weigh each contrast according to the relative abundance of that taxon. This author agrees with that assertion that increased significance should be attributed to changes in the more abundant species. The original un-weighted PPCS has also been shown to be more susceptible to sampling error (Brock 1977). Pinkham and Pearson noted this tendency as well, using the example of: a change of one individual will more profoundly alter the index from a 3-3 to a 3-2 contrast than it would if the abundance were higher: 324-325 to a 323-325. Though Pinkham and Pearson proposed a weighted modification (B<sub>2</sub>) it was not selected for use because of its inability to weigh contrasts when one taxon was absent from the pair. The following modifications to the IBS are being proposed by the author:

1. Species used in the paired contrasts should comprise at least

1% of the total population or have a density of at least 50 individuals/ ha (from a catch per unit effort estimate based on two electrofishing sweeps) from at least one site.

2. Species used in the paired contrasts will be weighed according to their abundance at both sites combined, using the following factors:

For species comprising 1-5% of the total, multiply the quotient by 1.0; for 5.1-10%, 1.25; for 10.1-15%, 1.50, for 15.1-20%, 1.75; for 20%, by 2.0 (See Table 5-B for example of application).

From the example demonstrated in Table 5-B, species D was eliminated from the contrast because it did not meet the 1% criterion. The remainder of the species were weighted accordingly, resulting in an increase in the PPCS from 0.26 to 0.44. The value from the modified PPCS would intuitively appear to better represent the true changes between these two hypothetical populations.

## Results and Discussion

The process of developing biocriteria in Vermont is in progress. Subsequently, the available data set is too small to present a conclusive discussion of the results. A few general trends have been observed and will be discussed together with specific objectives for on-going work.

The Department has, thus far, focused on extensively testing the Vermont IBI over a number of streams rather than intensively on a few streams. The distribution of IBI scores from 44 sites sampled prior to 1988 is skewed towards the higher values despite an

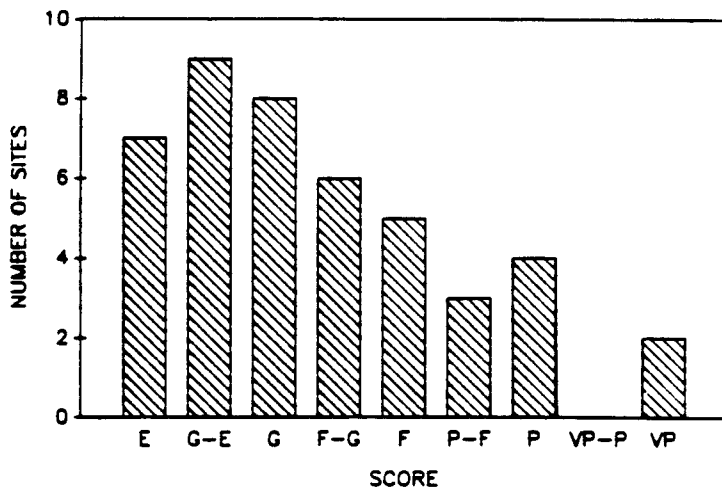


Fig. 4. Distribution of Vermont Index of Biotic Integrity scores for 44 sites.

attempt to include more degraded sites in the testing (Figure 4). Five of the six sites which were rated very poor or poor are known by the Department to be "trouble spots". Substantial water chemistry data exists from four sites which verify the low IBI scores. The Vermont IBI was judged to have fully responded to disturbance from chlorinated wastewater effluents, physical habitat degradation and ammonia toxicity. Sites which scored poor to fair, fair, and fair to good, seem to be exhibiting less definable intermediate impacts from cumulative nonpoint and point sources as well as physical habitat degradation. The six sites rating excellent were all cold water trout streams, five of which are located in the NEH ecoregion. At this point in the testing it appears that streams in the NEH score slightly higher than streams located in the NAPU. It is presently too early to speculate whether this tendency is due to general habitat quality or

merely a result of differential index scoring for streams with inherently different trophic composition.

The Vermont IBI has not shown a sensitivity to all types and levels of impacts. Abundance was dramatically reduced (90%) at two sites where the index failed to respond fully. One test site showed excessive BOD and chlorine levels while the other contained high levels of copper from mine drainage. A third site was exposed to routine dewatering from an upstream hydrogeneration facility. Below the facility all major species were present, however, overall abundance was reduced nearly 50%. The Vermont IBI was only 6 points lower at the impacted site indicating "good" conditions. The omission of three of Miller et al.'s "original" metrics is not considered responsible for these inconsistencies in the Vermont IBI. To determine this, the modification of Miller et al. was applied, as well as, the Vermont version plus the three omitted metrics. Neither IBI responded to a greater degree than did the nine-metric Vermont IBI at any of the three cases.

The Department believes the IBI concept to be sound and with potential for use as Biocriteria. The IBI not only integrates several community attributes into a single value, increasing the validity of that value, but through scoring each metric individually, the computation of the IBI also provides the biologist with an opportunity to examine various community attributes separately. This process facilitates the use of professional judgement by the biologist which is considered by the Department to be a vital

component of the total site evaluation.

The weighted PPCS has not been tested as extensively as the Vermont IBI. This index has been applied to eight contrasts (two sites each) on eight streams. Values at six degraded sites ranged from 0.02-0.33 while values at two unimpacted replicate sites were 0.56-0.71. For the weighted PPCS the question seems not whether it responds to changes in community integrity, but rather to what degree it responds and how will that translate into final biocriteria?

#### Information Needs

Further sampling will include a more intensive sample design which will focus on the spatial and temporal factors which effect the scoring of the two indices. Specific objectives for further sampling program (when data are combined with the past years information) are:

1. To characterize expected variation in both indices. This will be attempted by sampling a number of replicate sites which will be similar in physical and chemical characteristics.
2. To examine the effects of temporal variability within the low flow period of August to early October. A number of sites will be sampled once between mid-August and early September and again between late September and early October.
3. To better define the sensitivity of both indices. More sites which vary in extent of degradation will be sampled.
4. To evaluate the effectiveness of

using catch per unit effort data (CPUE) in describing abundance.

5. To contrast results from fish population indices with those from macroinvertebrate populations. Concurrent sampling of fish and macroinvertebrate populations will provide information on how evaluations from each trophic level may be used singly or together in making site evaluations.

An additional concern yet to be addressed specifically, is how to systematically involve professional judgement into specific biocriteria. Critical to this problem is quantifying the role of professional judgement in the decision making process. Prior to the anticipated 1989 completion of the proposed Vermont fish population biocriteria, other issues such as data quality, minimum sampling effort and habitat analysis methodologies will also be addressed.

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